

Designing the California Academy of Sciences Living Roof :An Ecological Approach



Rana Creek living architecture

CAS Project Overview



Golden Gate Park, San Francisco

- Renzo Piano Workshop
- Gordon Chong Partners
- ARUP Engineers
- SWA Landscape Architects
- Rana Creek - Living Architecture

- 197,000 sq. feet of Roof Area
- Five Undulating Domes
- Slopes in excess of 60 degrees
- Built-up Living Roof System
- Six inches of Soil -Semi Extensive
- Diverse Plant Assemblages
- Living Roof Observation Deck



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CAS Project Timeline



- 2002 Early Design Development
 - Plant Material Selection
 - Roofing System Demonstrations
 - Living Roof Education and Interpretative materials
- 2003 Research & Demonstrations
 - Phase I Mock-ups Construction and Installation
- 2004 50% Design Development
 - Phase I Mock-ups & Findings
- 2005 100% Design Development
 - Specifications and Drawings
 - Phase II Mock-ups Construction and Installation
- 2005 *Comprehensive Proposal*
 - Development of the Conceptual Design for a Scientific Research and Public Education Living Roof Program



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Entrance Rendering- Chong Partners



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Existing Site & Structure



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Rana Creek Ecological Design Criteria

PRINCIPLE

DESIGN CRITERIA

Ecological Reference

Uses indigenous plants adapted to local environments and plant communities, supports local species of fauna.

Balanced Capacity

In balance with nutrient availability, rainfall, and seasonal growing requirements of plants and physical constraints of roof.

Adaptation & Function

Plant material selection is based on adaptation to seasonal climatic variation and soil conditions. The roof is self-sustaining, self-regenerative, self-transcending and adapting.

Sustainable Yield

Does not rely on the abundance of irrigation, fertilizers, and maintenance. Contain healthy soils with active microbial communities.

Hydrologic Cycle

Integration of site and structure by capturing, storing, reusing, and conveying of storm water to and through the architecture and ground plane landscape.



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Rana Creek Design Principles : Ecological Reference



Living roofs
should...

- Provide habitat for migratory species of birds, butterflies and invertebrates.
- Improve site and water quality conditions for local reptiles, amphibians, and fish.
- Re-connect patches of habitat - links within corridors.



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Rana Creek Design Principles : Function



Living roofs
should be...



- Self-regenerative:
 - Reproduction
- Self-transforming:
 - Adapted to seasonality and life-cycle
- Supportive of complex plant, soil and microbial relationships:
 - Nutrient cycling
 - Carbon sequestration
 - Water Cycling



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Rana Creek Design Principles : Diversity = Stability



Living roofs
should...

- Provide seasonality - both cool season and warm season plants, early and late flowering species.
- Be comprised of annual flowering plants and long-lived perennial plants
- Contain diverse morphology and phenology



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CAS LEED Design Goals

Aesthetics

"It will seem as if they are lifting up a piece of the park and putting a building under it" -RP

Water Efficiency

Credits 1.1 & 1.2

Use of ET sensors, micro irrigation system- use of SS native plant materials. Use of reclaimed water.

Reduce Sound Attenuation:

Reduction of low frequency noise by 40 decibels
-deflection of higher frequency sound.

Innovation:

ID Credit 1.2

-Demonstrate sustainable architecture, Promote public awareness- "Roof as an exhibit and research station"
-Integrated Pest Management

Restore and Reconnect Wildlife Habitat:

Planting a diverse assemblage of plants adapted to San Francisco and supportive of local wildlife.

Energy Savings:

Estimated R value = R23 (when soil is dry)
Interior temperature approx. 10 degrees cooler

Decrease the Urban Heat Island Effect:

SS Credits 7.2

Roof temperature 40 degrees cooler

Storm Water Management:

SS Credits 6.1

36,000 gallon capacity in a one hour storm.
Reduce peak flows



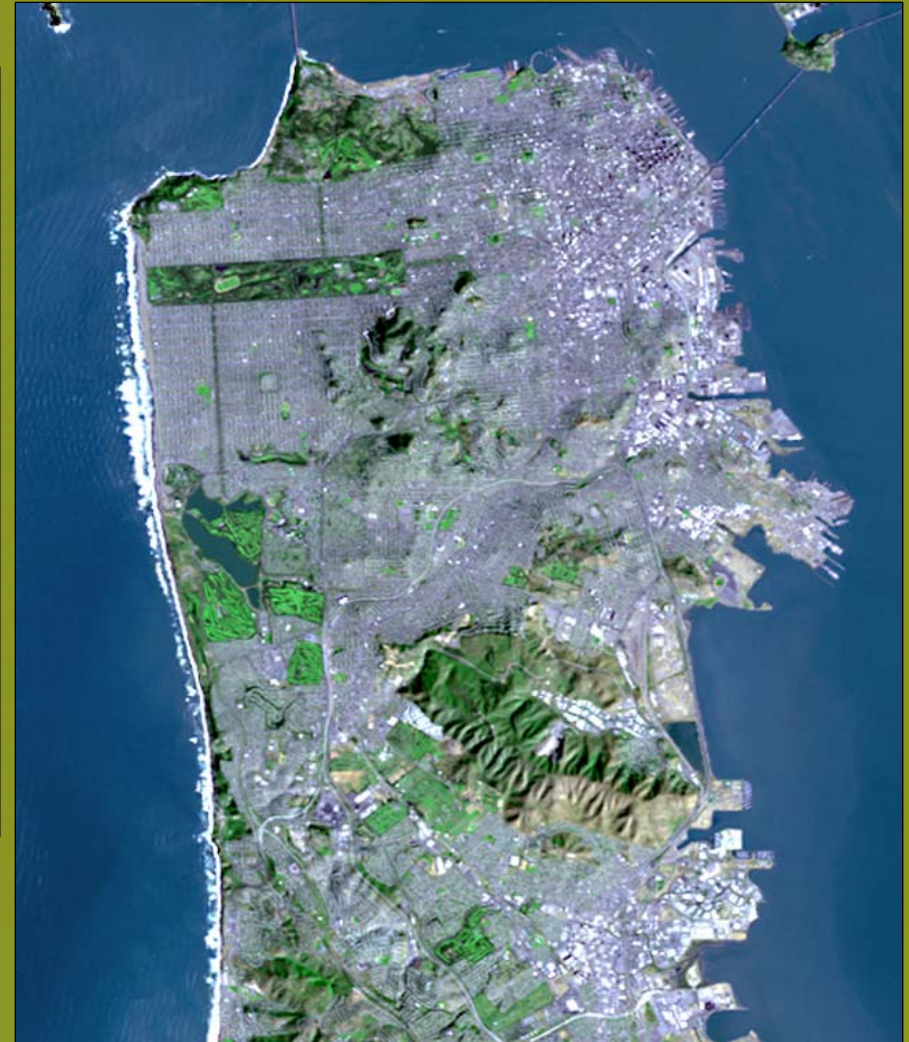
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Urban Dilemma : San Francisco, CA

- The Bay Area will soon contain **25%** (10 million people) of the state's population. ⁽¹⁾
- San Francisco County ranks **5th** in the country for population density. ⁽²⁾
- "Since the 1920s the amount of pavement associated with each new dwelling unit has grown by a **factor of five**."⁽³⁾

-Landscape Architecture

Magazine



Courtesy of PG&E/USGS



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Stormwater Dilemma: “Not So” Fun Facts



S.F. Beach Monitoring Stations

- “According to the State Water Resources Control Board, urban storm water runoff is the leading cause of water pollution in California.” ⁽⁴⁾

-SFEI

- In the last month alone, at just one of these beaches, water quality has not met State standards, 12 times. ⁽⁵⁾

- According to *Heal the Bay*, San Francisco Beaches were closed over 40 times in 2004. ⁽⁶⁾

- After 20 years, \$1.5 billion dollars, and a 190 million gallon stormwater “moat” system, they are still only controlling 85% of CSO’s. ⁽⁷⁾



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Urban Stormwater Solutions : Living Roof



- CAS designed soils retain 1 gallon per cu/ft. of soil.
- Yearly, the CAS roof retains 3.5 million gallons.
- Yearly, the runoff equals 87,305 gallons runoff.
- All of that runoff is detained and percolated into the ground plane.

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Preliminary Storm Water Calculations

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<i>Month</i>	<i>Fifty Year Average Rainfall (inches)</i>	<i>Volume Required to Reach Field Capacity (inches)</i>	<i>Water Retained on Roof (Gallons)</i>	<i>Excess Runoff (inches)</i>	<i>Runoff (detained) Gallons</i>
January	4.41	3.94		0.47	82067
February	3.8	3.94		0	0
March	2.79	3.94		0	0
April	1.37	3.94		0	0
May	0.56	3.94		0	0
June	0.14	3.94		0	0
July	0.02	3.94		0	0
August	0.05	3.94		0	0
September	0.24	3.94		0	0
October	1.04	3.94		0	0
November	2.62	3.94		0	0
December	3.97	3.94		0.03	5238
TOTAL	21.01	47.98	3581267.4	0.5	87305



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Urban Dilemma : Los Angeles, CA



- The Los Angeles five-county area has a population of 20.6 million. By land area, it is the largest city in the United States and would be the fourth largest state.



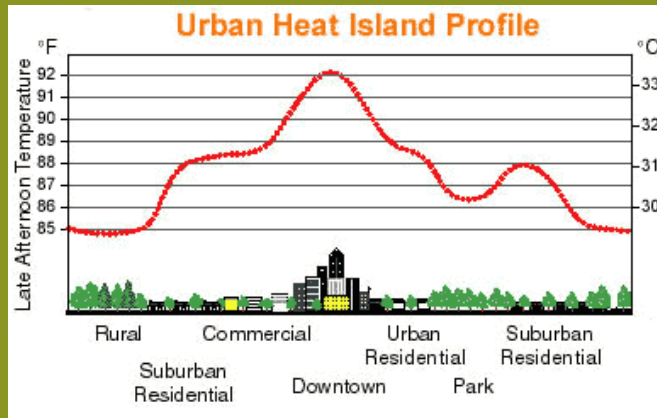
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Urban Dilemma : Los Angeles, CA “Joni was right”



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Urban Heat Island Effect: “Not So” Fun Facts



Heat Island & Energy Use

- HVAC systems account for **65.2%** of total U.S. electricity consumption.
- In Los Angeles the demand for electric power rises nearly **2%** for every **1°F** the daily maximum temperature rises.
- Los Angeles has seen its average temperature rise approximately 1°F every decade since 1950.
- the impact of the heat island effect costs the Los Angeles ratepayers about \$100,000 per hour, about **\$100 million per year**. (8)



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Heat Island Solution : “Cool Roofs”



- Cool roofs save building owners **40-70%** in annual cooling energy use
- Cool roofs are generally expected to reduce utility bills by **3 to 10%**
- Title 24, *California's Energy Efficiency Standards Buildings*, provide incentives for cool roofing solutions such as \$10-25 cents/sq. ft. payouts from California utility companies.



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Heat Island Solution : Living Roof



- Mitigating heat island effect: **reduced roof reflectivity, provides urban vegetation that removes airborne particles, and volatile organic compounds.**

- The Gap Headquarters Living Roof is projected to pay for itself in energy savings within **3 years.**

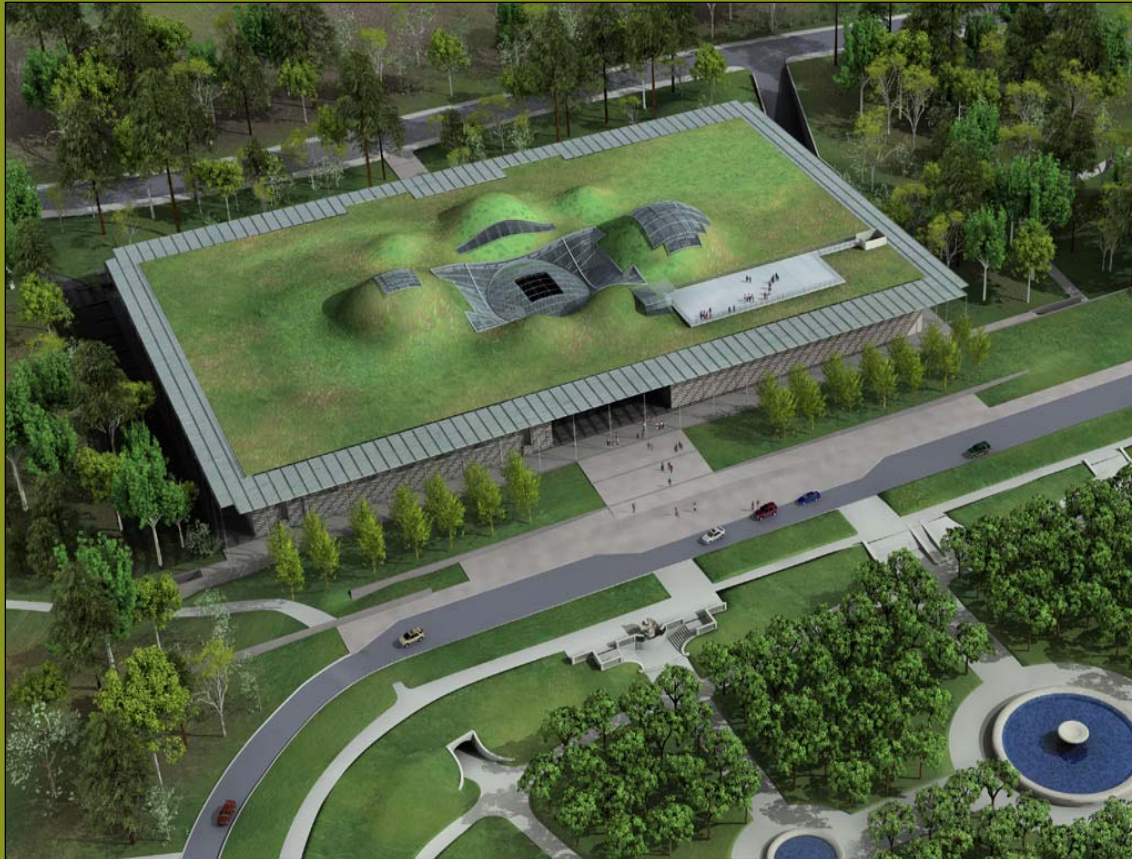
- Energy savings **3x** greater than that of a conventional roof membrane.

- 900 sq. ft. Living Roof can "evapotranspire" up to **40 gallons of water in a day**, which is like removing all the heat produced in four hours by a small electric space heater.(8)

Living Roofs result in "better air quality" and "lower air temperatures" BUT... Title 24 currently does not provide standards and provisions.



San Francisco : *Design Development Example*



The California Academy of Sciences



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CAS Mock-Up Phase I

Design Development Objectives:

- Demonstrate Membrane Type and System Components
- Compare Soil Type & Composition
- Develop Planting, Irrigation, Drainage Design
- Monitor Irrigation Requirements
- Develop Soil Stabilization Methods
- Test Plant Performance and Adaptability



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CAS Test Soil Type and Soil Composition

Initial soil tested: *"Industry standard"*

Pumice	65%
Aged bio compost	10%
Peat Moss	25%
Commercial fertilizer	2 lbs/yard

Weight = 28 pounds /cubic foot



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CAS Soil Design Development

Soil Composition

Aged bio compost	15%
Coarse sand	15%
Red Scoria	35%
Coco coir	25%
Mycorrhizal fungi	.5 lbs./yd.
Slow Release Fertilizer (after plant establishment)	
<i>Total Weight</i>	<i>+33 lbs./cu. ft</i>



VAM



Mycorrhizae Test



CAS Soil Retention & Drainage

Criteria:

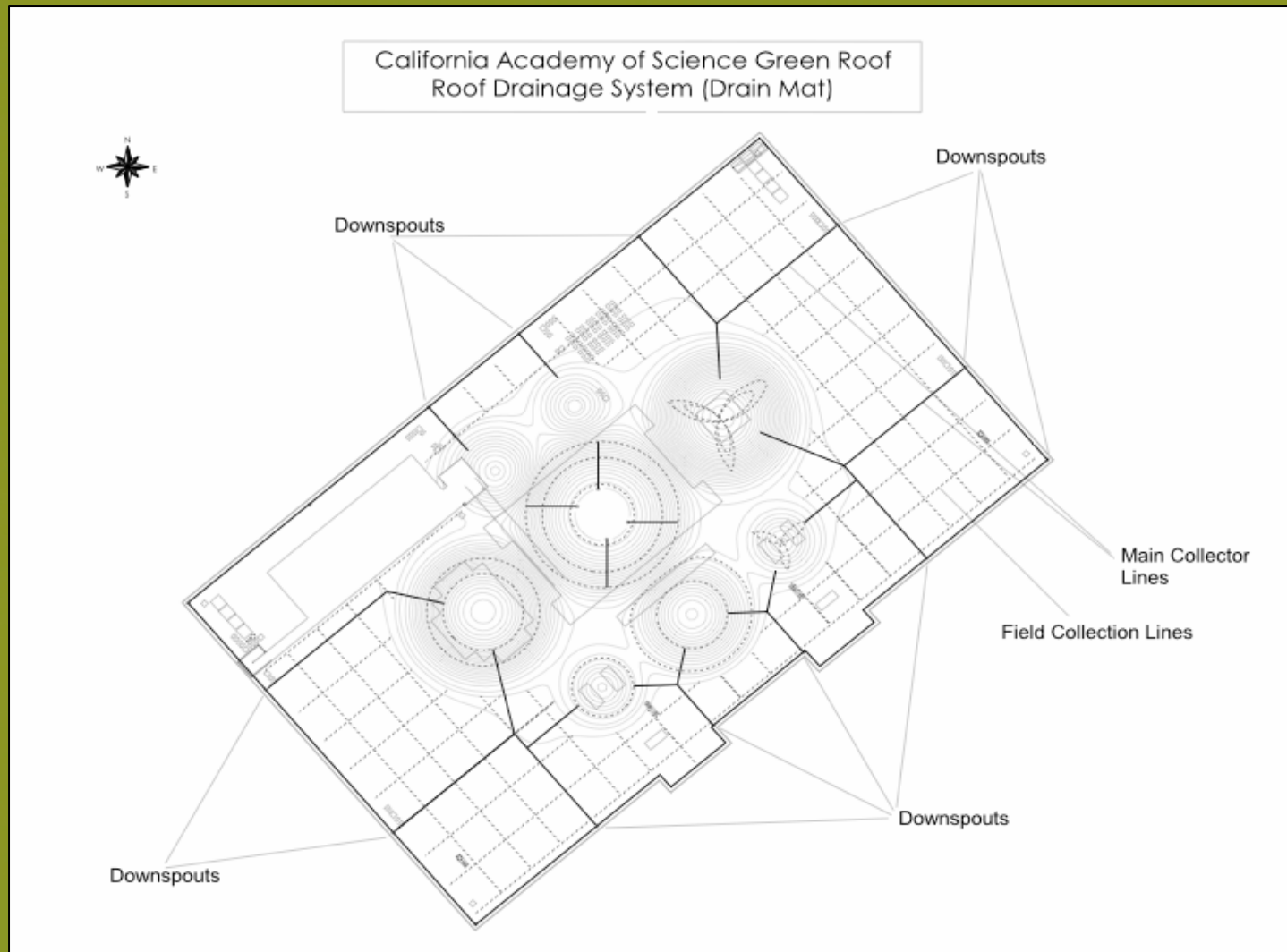
- Retain soil on steep slopes
- Retain moisture at mid slope
- Accommodate drainage
- Convey sub surface and surface run off



Preliminary Stabilization Concept



CAS Drainage Design Development



Drainage and Slope Stabilization Design



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CAS Soil Retention

Soil Retention and Drainage:

Four erosion control blankets of different weights and life expectancy were tested



- Jute netting:
 - 1 to 2 years
- Turf Coco reinforcement blanket:
 - 2 years
 - 7 years
- CFO72B Double Organic Net Coconut Blanket:
 - 3-4 years



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CAS Plant Design Criteria

Criteria:

- Plant materials are indigenous to the San Francisco Bay Region.
- Plants are selected for tolerance to harsh conditions, low nutrient, water, biomass height and attraction to fauna.

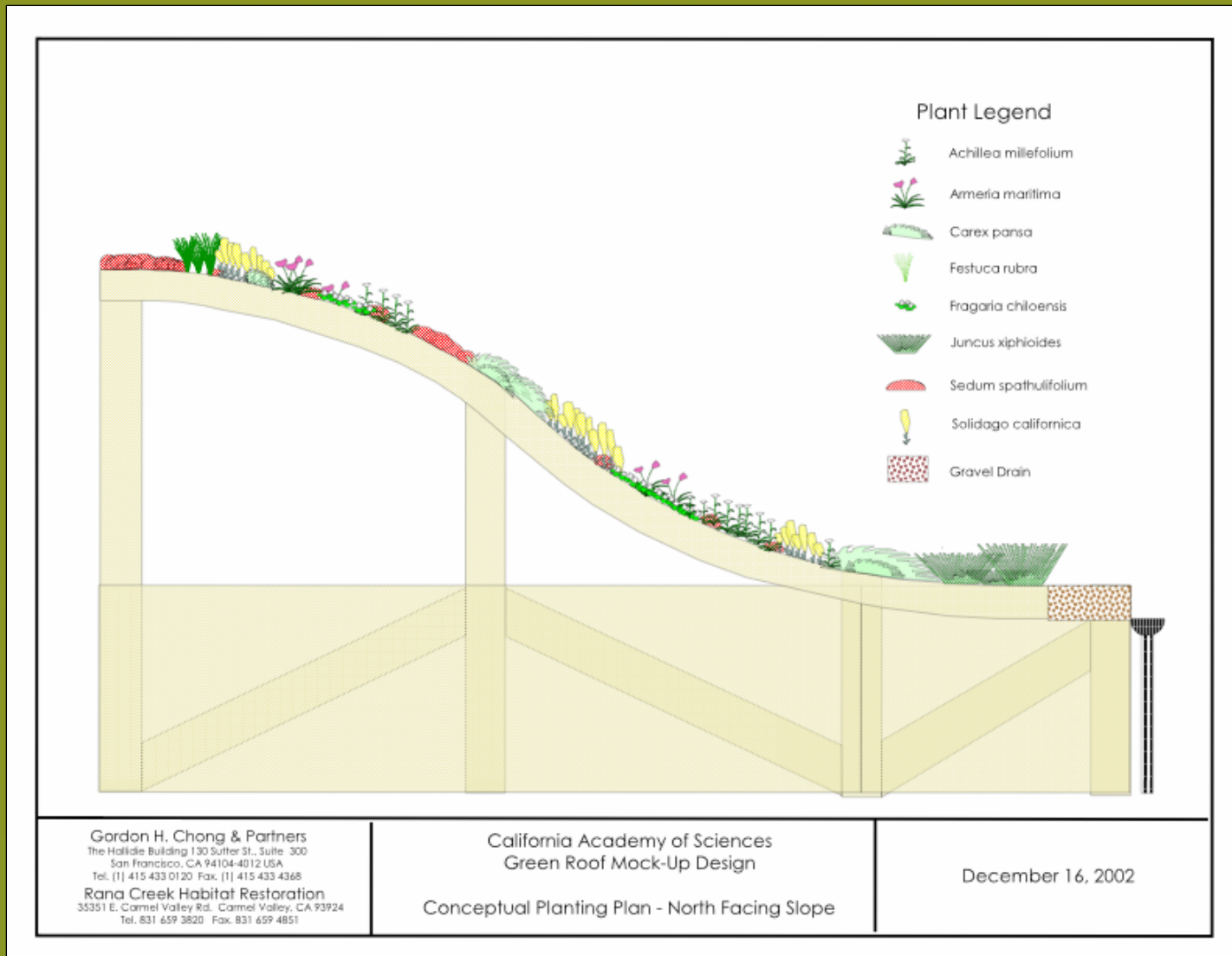


Species	Common Name	Survival	70% cover (3 months)	Plant Height	Utilization
Herbaceous perennials					
<i>Achillea millefolium</i>	yarrow	yes	yes	12"	flies/bees/lady bugs
<i>Armeria maritima</i> ssp. <i>californica</i>	sea thrift	yes	yes	6"	bees
<i>Fragaria chiloensis</i>	beach strawberry	yes	yes	3"	bees
<i>Heuchera micrantha</i>	alum root	yes	no	5"	hummers
<i>Prunella vulgaris</i> var. <i>lanceolata</i>	self heal	yes	yes	6"	bees/ladybugs
<i>Satureja douglasii</i>	yerba buena	yes	no	3"	unobserved
<i>Solidago californica</i>	goldenrod	yes	yes	16"	bees/ladybugs
<i>Stachys bullata</i>	hedge nettle	yes	yes	14"	hummers
<i>Trifolium wormskioldii</i>	cow clover	no	no		n/a
Grasses					
<i>Festuca rubra</i>	red fescue	yes	yes	14"	butterflies
<i>Festuca idahoensis</i>	Idahoe fescue	yes	yes	8"	unobserved
<i>Koeleria macrantha</i>	June grass	yes	no	8"	unobserved
Emergent Wetland Species					
<i>Juncus patens</i>	spreading rush	yes	yes	12"	unobserved
<i>Juncus xiphioides</i>	iris leaved rush	yes	yes	12"	unobserved
<i>Carex tumulicola</i>	foothill sedge	yes	yes	8"	unobserved
<i>Sisyrinchium bellum</i>	blue eyed grass	yes	yes	6"	native bees
<i>Carex pansa</i>	sand sedge	yes	yes	6"	unobserved
Succulents					
<i>Sedum spathulifolium</i>	sedum	yes	no	3"	butterflies
<i>Dudleya farinosa</i>	dudleya	yes	yes	8"	unobserved
Wildflowers					
<i>Eschscholzia maritima</i>	poppy	yes	n/a	6"	bees/butterflies
<i>Lupinus bicolor</i>	lupine	yes	n/a	6"	unobserved
<i>Lasthenia californica</i>	gold fields	yes	n/a	4"	butterflies
<i>Layia platyglossa</i>	tidy tips	yes	n/a	4"	unobserved
<i>Dichelostemma capitatum</i>	blue dicks	no	no		n/a
<i>Plantago Erecta</i>	California Plantain	yes	yes	2"	butterflies



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CAS Proposed Plant Assemblage



Mock-up Design Development



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CAS Plant Assemblage

After 90 Days



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Native Plants of the California Academy of Sciences Living Roof

Perennials



Beach Strawberry | *Fragaria chiloensis*
10% OF TOTAL PERENNIALS

Appears on coastal grassland and beaches from Central California Coast to Alaska. Produces small edible fruit attractive to variety of birds.

Sea Thrift | *Armeria maritima*
30% OF TOTAL PERENNIALS

Ocean bluffs, ridges, grasslands from Southern California to Oregon. Pom pom like ball flowers attractive to variety of butterflies and moths.



Self Heal | *Prunella Vulgaris*
25% OF TOTAL PERENNIALS

Moist meadows and forest edges throughout California. Large tubular flowers attractive to hummingbirds and bumble bees.

Stonecrop | *Sedum spathulifolium*
35% OF TOTAL PERENNIALS

Rock outcrops, bluffs and canyons from Southern California to British Columbia. Host plant for San Bruno Elfín Butterfly (nectar for adults, foliage for larvae), a threatened species with limited distribution in San Francisco Bay region. It is also nectar plant for Hairstreak Butterfly.



Annuals



Coast California Poppy | *Eschscholzia californica*
15% OF TOTAL ANNUALS

Annual or perennial flower found along coastal California and Oregon. As the State Flower, this plant puts the gold into the Golden State, and is a profuse bloomer that provides nectar for bees and butterflies.

Miniature lupine | *Lupinus bicolor*
25% OF TOTAL ANNUALS

Common annual wildflower found throughout California. It's flowers provide nectar for bees and attracts a variety of beneficial insects.



Goldfields | *Lasthenia californica*
25 % OF TOTAL ANNUALS

Abundant annual wildflower of many habitats throughout California and Parts of Oregon and Arizona. The tiny bright yellow daisy-like flowers are very attractive to many beneficial insects.

California plantain | *Plantago erecta*
20% OF TOTAL ANNUALS

Annual species found on sandy, clay or serpentine soils, grassy slopes and flats from Baja to Oregon. Host plant for a variety of butterfly species particularly Checkerspot.



Tidy Tips | *Layia platyglossa*
15% OF TOTAL ANNUALS

Common annual wildflower found throughout coastal ranges and Central Valley of California. Attracts beneficial insects like parasitic wasps and pirate bugs that feed on pest insects.



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CAS Phase I Preliminary Findings

Plant materials:

Selected 4 plants that achieved 70% cover four months

Irrigation:

May -September irrigation equaled 1/4 gallon/cubic foot/week.

Selected overhead pop-up system over sub surface system, to be use for plant establishment and severe drought.

Soil Retention:

Of four blankets tested, selected a seven year blanket. Open weave facilitated tillering and root growth.

Drainage:

Selected gabion basket over typical drain pipe and gravel.



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CAS Mock-Up Phase II

February 2005

Design Development Objectives:

- Monitor performance and adaptability of assemblage.
- Monitor new soil mixture and composition
- Monitor irrigation requirements
- Install & Test gabion stabilization methods
- Conduct storm weather simulation
- Conduct earthquake resistance tests



Webcor - Hayward, Ca.



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CAS Mock-Up Phase II

February 2005



Webcor - Hayward, Ca.

February 2005



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CAS Mock-Up Phase II



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CAS Mock-Up Phase II

Day of Planting



Day of Installation- Architects observe challenges of slope



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CAS Mock-Up Phase II

After 7 Days



"Underwire Bra" Installation



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CAS Mock-Up Phase II

After 25 Days



Plant and Wildflower Establishment



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CAS Mock-Up Phase II

After 45 Days



Plant and Wildflower Establishment



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CAS Mock-Up Phase II

After 90 Days



Plant and Wildflower Establishment

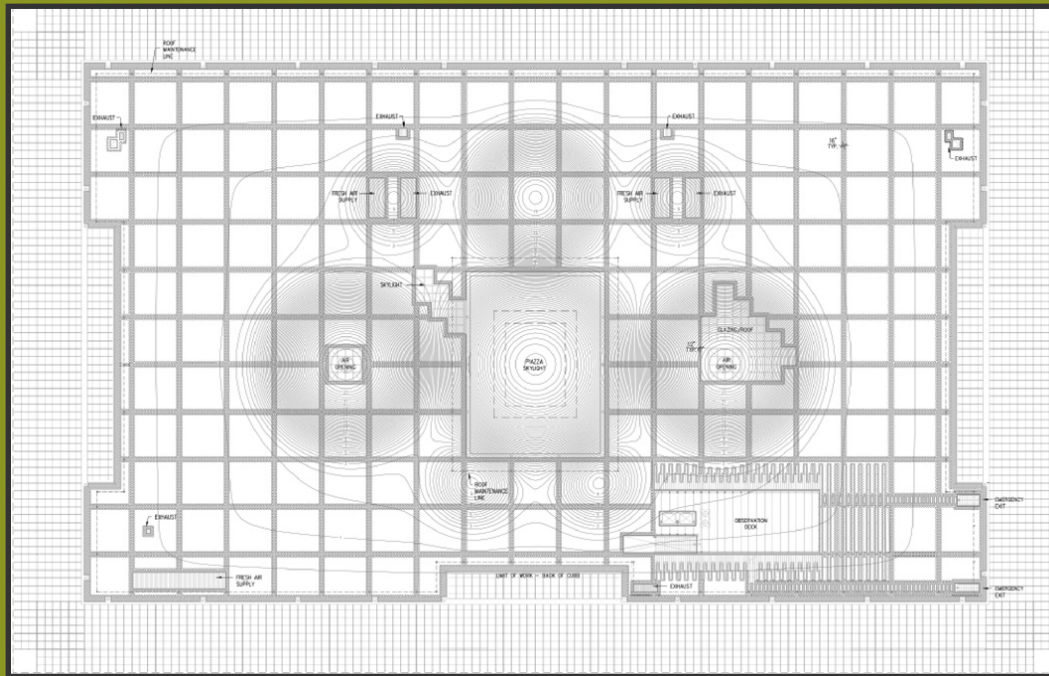


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CAS The Next Steps

Comprehensive Proposal

- Rana Creek is committed to the success of the Academy's Living Roof.
- We hope to continue working with the Academy to carry out Renzo Piano's Living Roof Design to its full potential.
- We're currently developing a *Comprehensive Proposal* to:



The Final Design Phase

- Contract Grow Plant Materials
- Develop Conceptual Long-term Research Program (CASLABS)
- Coordinate a Public Education Program with Academy Staff
- Install, Maintain & Monitor the Living Roof
- Integrate a Regional Green Roof Initiative
- Cultivate Funding Sources and Grants



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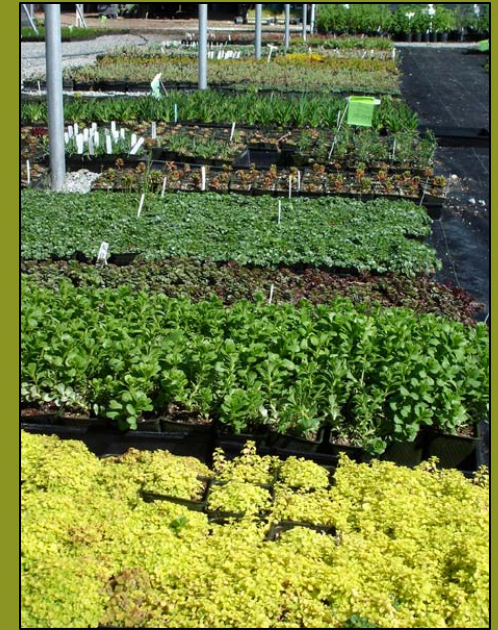
CAS Rana Creek Nursery Grow-Out



Rana Creek Nursery

Propagation Phases:

- Sight Specific Seed Collection
- Foundation Plant Propagation
- Production and Grow-out:
-1.8 million propagules



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CAS Rana Creek Nursery Grow-Out

Developing the Coconut Fiber *Bio-Tray*

Criteria:

- Provide immediate cover & root protection
- Develop alternative to sedum carpets & plastic trays
- Develop a biodegradable product
- Utilize waste material
- Harvest sustainable materials from Brazilian Amazon Rainforest.
- Support indigenous cooperative enterprise:

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TIFF (Uncompressed) decompressor
are needed to see this picture.



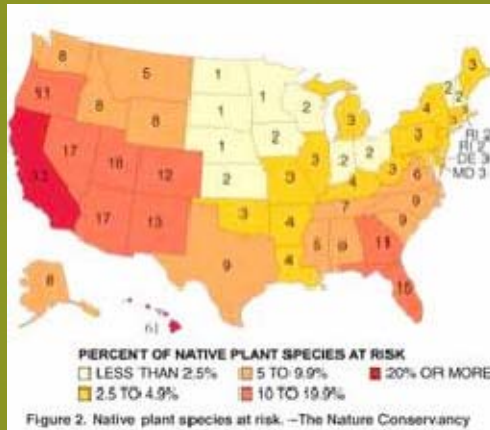
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CAS Living Architecture Biodiversity Study



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CAS LABS - Why CAS LABS ?



- California is the most populated and fastest growing state...
- It supports 2,500 endemic species & has lost over 70 percent of these natural habitats.
- The Biodiversity “Hotspot” in the U.S. of 34 in world.
- The current need for comprehensive, regimented green roof research is crucial to the further development of policy and design of roof systems in Mediterranean climates.
- “The rich tradition of exploring, explaining and protecting the natural world,” the Academy's mission for over 150 years.



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CAS LABS Biodiversity Research Examples

- Establish rare plants and plant communities
- Preserve and increase gene pools of selected threatened species (most endemic and endangered species of S.F. Peninsula)
- Monitor the effects of “Invasive” species (recruiters and/or volunteers)
- Study the effects of Biodiversity on:
 - Stormwater Purification
 - CO₂ sequestration
 - Microbial communities & activity
 - investigations on bacteria, fungi, algae and protozoans



Vernal Pool Thomes, Ca

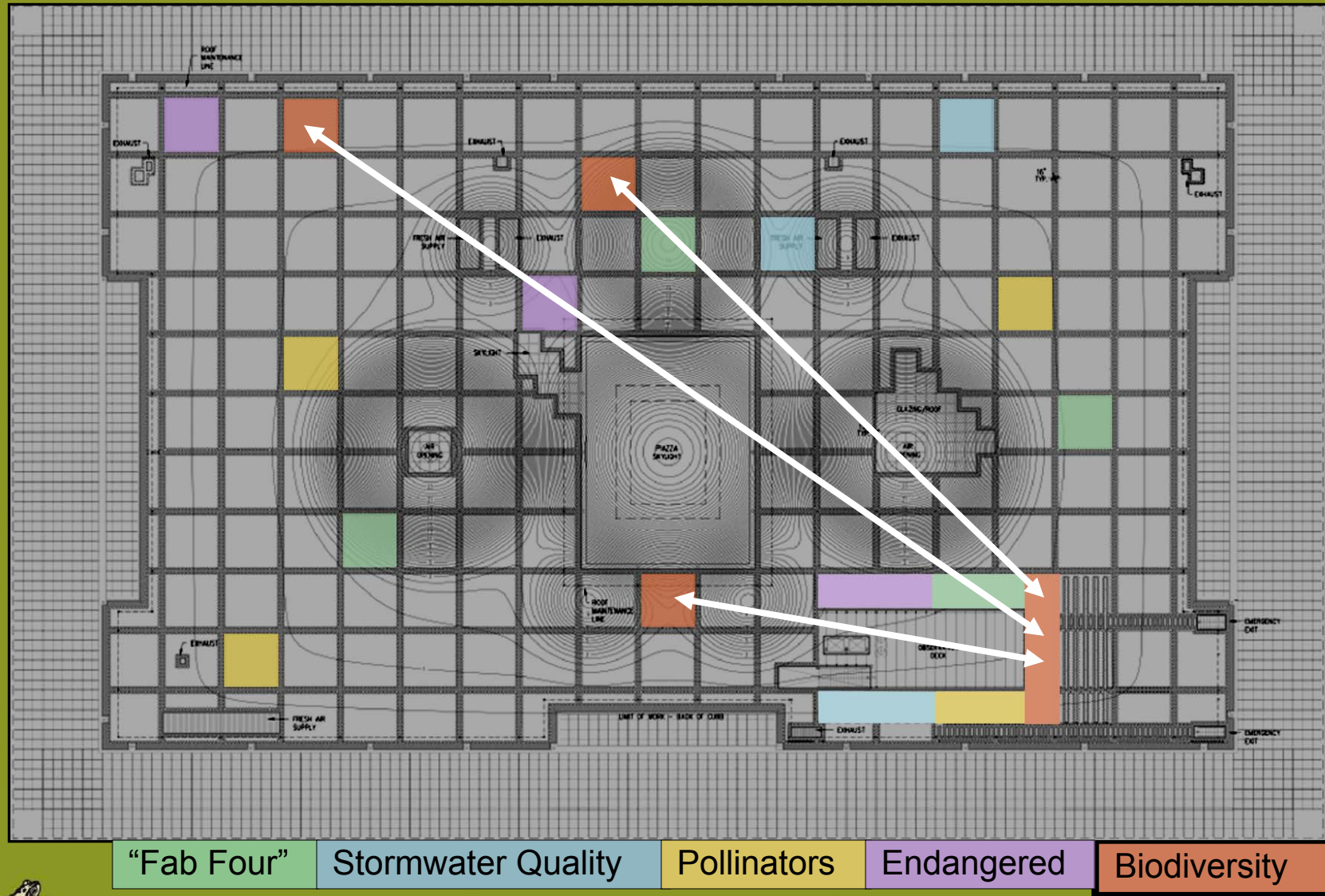


Gap Headquarters San Bruno, Ca



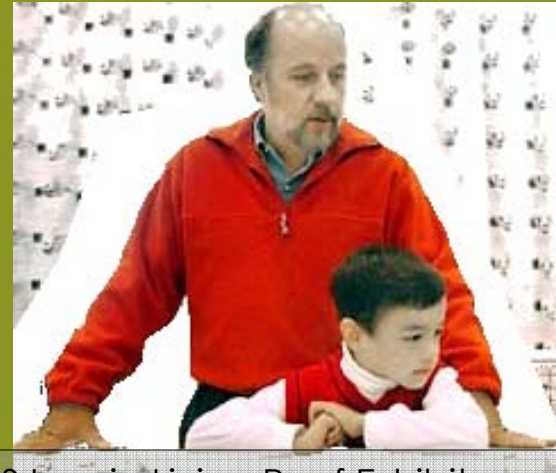
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CAS LABS Integrated Research & Education



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CAS Public Education



- CAS Iconic Living Roof Exhibit
- Demonstrate Living Architecture
- Interpret & teach Urban Ecology
- Support scientific career development
- Integrate interactive ecology models with research for grade school education.
- Link living architecture to community through web-based Research and Education Network



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